Additional Information Request # 13

Management and Mitigation of Type 2 Mine Rock

Related Comments:

CEAR #547 (Environment Canada)

CEAR #550 (Natural Resources Canada)

In IR 9.11.1, SCI was requested to clarify the measures that will be implemented to prevent or control ARD from the PAG waste rock (Type 2 mine rock).

In its comments on SCI's response, Natural Resources Canada noted SCI's statement that both the Type 2 PAG waste rock and process solids would be placed or relocated to the mined out open pits, when available, and managed under submerged conditions. Natural Resources Canada noted that these deposited solids will interact with the oxygenated water column at the water-waste interface and to a certain depth below, resulting in surface oxidation and release of COPCs to the water cover in the long-term. Consequently Natural Resources Canada requested information on certain water quality aspects of closed-out open pits containing submerged Type 2 PAG materials and their management strategy. Natural Resources Canada also requested that SCI provide information on any circumstances that would transport COPCs enriched pore water from the submerged, weathered PAG wastes to the surface water cover, noting that this may be a long-term pit water quality management issue.

Environment Canada also raised a number of questions related to SCI's response and would like to ensure water quality is adequately protected, particularly in the Bamoos Lake watershed. These questions relate to seepage and surface drainage through the temporary PAG waste rock stockpiles, the effectiveness of this mode of temporary PAG rock storage, and whether the drainage divide may be altered due to the presence of the PAG rock stockpiles.

In order to understand how acid rock drainage from the temporary PAG rock stockpiles will be managed:

1. Provide information on the long-term surface and pore water quality aspects of closed-out open pits containing submerged Type 2 PAG materials and their management strategy, if any. Include comparable examples from other open pit mining projects.
2. Comment on the possibility that some of the contact water may escape uncaptured from the temporary Type 2 waste rock pile by means of seepage through the subsurface. Identify estimated volumes, where are they going, and impacts, if any, on surface water quality.
3. In regard to the northern-most temporary Type 2 PAG waste rock stockpile, which is reported to be very close to the edge of the Bamoos Lake watershed, comment on the potential for the drainage divide to shift as a result of the changes in topography associated with the establishment of northern-most temporary Type 2 waste rock stockpile.

SCI Response:

The responses to the information requests are numbered to correspond to the requests above.

1. Long-term pit water and porewater quality

As NRCan is well aware, underwater storage was identified as the primary proven technology for the safe management of sulphide bearing mine materials in the Mine Environment Neutral Drainage (MEND) decade-long research program that was administered by NRCan. The reports on under water storage of sulphide mine materials are numerous (see MEND references below) and the concepts and processes that mitigate weathering in general and oxidation of sulphide minerals, specifically, are well known. Although there can be small residual effects of oxidation on unweathered materials by dissolved oxygen in the water overlying the flooded materials, these processes are many thousands to millions of time slower that what can occur on land when rock or other mine materials are exposed to air and therefore the potential effects on water quality are also thousands to millions times less. Weathered material such as mine rock, that has been temporarily stored on land before flooding, may have soluble products that may require management when the materials are flooded. Both fresh and weathered materials will be destined for permanent underwater storage and these are discussed below in the context of management and water quality effects.

One or more satellite pits at the Marathon project will be available to store fresh Type 2 process solids and fresh to moderately weathered Type 2 mine rock. The process solids will be delivered to the pit(s) directly from the mill and will be deposited so that the solids will not be weathered and therefore there will be no weathering products associated with the process solids. The Type 2 mine rock will have undergone some degree of weathering during temporary storage on surface during the mining operation. And although underwater storage will prevent further oxidation and leaching, there will be some soluble COPCs associated with the moisture on the weathered rock that may dissolve into the porewater of the rock when it floods. The porewater may therefore contain concentrations of COPCs above background values. The effects of porewater and weathering products are discussed separately for the under water management of fresh Type 2 process solids and weathered Type 2 mine rock, respectively, below.

Separation of Type 1 and Type 2 process solids will continue until near the end of mine life. When capping of the Type 2 process solids in the PSMF by Type 1 process solids, the Type 2 process solids produced by the mill will be directed and deposited into one or more pits. Type 2 process solids will be deposited in the pits until the PSMF is filled with Type 1 process solids. At that time, the process solids will be mixed and will be deposited concurrently in the pit(s) until closure. Therefore, much of the surface of the underwater process solids in the pits will consist of a lower sulphur material than is typical of Type 2 process solids.

The Type 2 process solids deposited in the pits will be fresh from the mill and therefore, the porewater in the process solids will be similar to the mill process water. The concentrations associated with the process water were measured in the 2013 pilot plant metallurgical test and the results are presented in Table 1 below. As shown in the table, the concentrations of COPCs in the process water are less than the lower of either the PWQO or CWQG values for all COPCs. Therefore any movement of porewater from the underwater process solids to the overlying water will not negatively affect water quality in the pit(s).

Another potential source of COPCs from the unweathered underwater process solids is the oxidation of the sulphide minerals at the surface of the process solids by dissolved oxygen in the pit water. This potential underwater oxidation was tested in the laboratory in well-aerated test cells with flooded process solids and the methods and results are described in SID 5 (EcoMetrix, 2012). The resulting release of COPCs from the surface of the process solids actually represents a combination of oxidation and the diffusion of COPCs from porewater in the process solids and are given as a flux that represents the mass of COPC released (mg) per unit surface area of the top of the process solids in the pit (m^2) per week. The concentration in the pit water can then be calculated by applying the surface area of the process solids and the rate of water flow through the pit. The area of pits that will be occupied by the Type 2 Process solids was estimated to be 10.2 ha in Pit 2 and 32.3 ha in the main pit for a combined total of 42.5 ha or 425,000 m^2. The flow through the pits after mine closure will be approximately 1.96 Mm^3/a. The predicted steady state incremental COPC concentrations in the pit water were calculated from these values and are shown in Table 2. The predicted incremental values are well below the water quality benchmark values for the Pic River and therefore, no adverse effects are expected in the long term as a result of storage of the Type 2 process solids underwater in the pits.

The water quality in the pit will also be monitored as the pit fills with water. If the small amount of oxidation at the process solids surface negatively affects pit water quality, mitigation measures will be applied. Mitigation of surface oxidation of the underwater process solids by dissolved oxygen can be readily achieved by covering the surface of the solids with a layer of material that acts as a diffusion barrier. Only a thin layer of inert material is needed to reduce fluxes of dissolved oxygen downward and COPCs upward to extremely low values. A 0.3 m thick layer of overburden or other similar non-sulphide material can be placed over the process solids. After flooding, the covered process solids will be isolated from the overlying water by the cover layer and there will be virtually no release of COPCs from the process solids to the pit water.

The Type 2 mine rock in temporary on-land stockpiles will have undergone some weathering before being deposited in the pit(s) and flooded. The soluble weathering products can then mix with the water that floods the rock and can affect concentrations in the porewater. The Type 2 rock will be sampled and tested in the laboratory prior to relocation to the pit(s). The testing will quantify the soluble constituents that are available to the porewater when flooding occurs. The test results will provide a basis on which to decide if the flooded rock may require additional mitigation, prior to relocating the rock to the pit(s), to protect the quality of the pit water in the long term.

There are a few potential approaches for mitigation of effects of the soluble COPCs on pit water quality, if warranted. One is to provide pH adjustment to the rock by adding a lime slurry to the rock as it is being relocated from the temporary stockpiles to the pit(s). Although acidic pH is not anticipated in the Type 2 rock, some metal leaching will have occurred and a pH increase with lime will have a similar effect as water treatment and will reduce dissolved metal concentrations so that the porewater in the flooded rock will have alkaline pH and low metal concentrations in the pit. The results of the testing of the weathered rock will provide a lime dosing rate that will optimise metal concentrations. The other potential mitigation measure involves the placement of a diffusion barrier over the Type 2 rock that will function in the same manner as a cover over the Type 2 process solids as described above. A cover layer of either overburden or Type 1 rock can be placed over the flooded Type 2 rock to minimize transfer of COPCs from the Type 2 porewater to the pit water. During operations and before the rock is relocated to the pits, the cover layer can be tested in the laboratory with actual rock from the temporary Type 2 stockpiles. After covering and flooding, the Type 2 rock will be effectively isolated from the pit water and the water quality in the pit will be protected over the long term.

In pit storage of mine materials such as process solids and mine rock has been proposed and utilized at many mine sites in Canada and around the world. The main reference for in-pit storage to date is MEND (1995): Review of In-Pit Disposal Practices for the Prevention of Acid Drainage - Case Studies, Mend Report 2.36.1 (available at: http://mend-nedem.org/category/uncategorized/). One case study, the Owl Pit, provides an example of relocation of highly weathered and acidic rock placed in a pit with mitigation of acidic pH by the addition of limestone. The in pit water quality was good for this early attempt at mitigation of weathered and acidic rock even without the use of lime for pH adjustment. With the information on management of acidic and metal leaching rock gained since the 1990s, the results of relocating weathered Type 2 rock at the Marathon mine are expected to be vastly better than those at the Owl pit.

In-pit storage of mine materials is being updated in a MEND project and a report should be available in 2014.

2. Potential for uncaptured contact water from temporary Type 2 stockpiles

The temporary stockpiles for Type 2 mine rock will be located in catchment areas in which surface and groundwater flow naturally migrates to the open pit(s) and therefore will be captured and managed as site water in the PSMF. The grade of the storage area for the Type 2 mine rock will be toward the pit(s).

The groundwater flow at the temporary Type 2 rock storage areas was assessed and reported on in AIR 6. The results showed that all subsurface flow occurred to the pits. As a confirmation of this containment of groundwater, monitoring wells will be installed and sampled regularly to confirm that contact water has not migrated away from the pit catchments. The details of the monitoring program will be developed during the permitting phase of the project. If any seepage from the Type 2 mine rock is detected, simple contingency measures can be implemented. These can include the construction of a cut-off and interceptor ditch system that will capture seepage and can direct water to the pit(s) as required before the rock is relocated.

3. Potential for watershed shift at northern Type 2 temporary stockpile

Groundwater flow boundaries can shift as a result of mounding of a water table when fill is added to natural ground. The mine rock has a very high permeability and experience at other mine rock facilities shows that there is no appreciable mounding of the water table within mine rock stockpiles and therefore there should be no effect on existing groundwater flow boundaries. Nonetheless, a groundwater monitoring program can be implemented on the northern boundary of the temporary stockpile to ensure that such a shift has not occurred during operations. Contingency measures such as those discussed above can be implemented if such a shift is detected. The monitoring plan and details of potential contingency measures will be provided in the permitting phase of the project.

The northern most Type 2 temporary stockpile has been sited within Sub-basin 103 which drains to the open pit. It is anticipated that (i) the sub-basin 103/104 drainage divide would be field-confirmed and staked to limit the extent of mine rock placement, and (ii) the surface of the stockpile will be graded to ensure surface drainage towards the respective open pit. As a contingency, if mine rock does extend into Sub-basin 104 or surface drainage is towards Sub-basin 104, surface drainage can be intercepted and directed to the open pit with collector ditching. Sub-basin 104 drains to the Pic River and not to the Bamoos Lake Watershed.

Table AIR 13-1: Concentrations of COPCs in Process Water during Operations.

COPC	PWQO (mg/L)	CCME (mg/L)	Process Water Chemistry (mg/L)[1]
Aluminum (Al)	0.075	0.1	0.0612
Arsenic (As)	0.005	0.005	0.00045
Cadmium (Cd)	0.0001	0.00001	0.00001
Cobalt (Co)	0.0009	-	0.00012
Copper (Cu)	0.005	0.002	0.00124
Iron (Fe)	0.3	0.3	0.01
Molybdenum (Mo)	0.04	0.073	0.0179
Nickel (Ni)	0.025	0.025	0.00238
Lead (Pb)	0.001	0.001	0.00005
Selenium (Se)	0.1	0.001	0.0003
Uranium (U)	0.005	0.015	0.000101
Vanadium (V)	0.006	-	0.0014
Zinc (Zn)	0.02	0.03	0.001

[1] Based on 2013 pilot plant metallurgical test

Table AIR 13-2: Predicted incremental Concentrations in Pit Water from Underwater Type 2 Process Solids.

COPC	Units	Pic River Water Quality Benchmark	Background Pic River Water Quality	Incremental Pit Water Concentration from Type 2 Process Solids
Sulphate (SO_4^{2-})	mg/L	No Value	2.6	9.3
Aluminum (Al)	mg/L	0.075[1]	0.040	0.0011 [2]
Arsenic (As)	mg/L	0.005	<0.0010	0.000041
Cadmium (Cd)	mg/L	0.00009	<0.000090	0.0000035
Cobalt (Co)	mg/L	0.0012	0.0012	0.0000038
Copper (Cu)	mg/L	0.005	0.0040	0.00046
Iron (Fe)	mg/L	2.7	2.7	0.00061 [2]
Molybdenum (Mo)	mg/L	0.04	<0.0010	0.00073
Nickel (Ni)	mg/L	0.025	0.0050	0.00010
Lead (Pb)	mg/L	0.001	0.0014	0.0000065
Selenium (Se)	mg/L	0.001	<0.00040	0.000028
Uranium (U)	mg/L	0.005	<0.0050	0.000031
Vanadium (V)	mg/L	0.006	0.0050	0.000038
Zinc (Zn)	mg/L	0.020	0.011	0.00021

NOTES:

1 - Dissolved concentration

2 - Based on loadings from Type 2 process solids. Actual concentrations are expected to be controlled by solubility, as discussed in SID #5

MEND REFERENCES ON SUBAQUEOUS STORAGE OF SULPHIDE MINE MATERIALS

MEND 2006. Case Study Assessment – Subaqueous Tailings Disposal in Mandy Lake Flin Flon, Manitoba, MEND Report ID: 9.2b

MEND 2001. Subaqueous disposal of reactive mine tailings, Louvicourt Mine test cells: Geochemical sampling and analysis, MEND Report ID: 2.12.1c

MEND 2001. Reactivity assessment and subaqueous oxidation rate modelling for Louvicourt tailings, MEND Report ID: 2.12.1d

MEND 2001. MEND Manual, MEND Report ID: 5.4.2

MEND 2001. Evaluation of man-made subaqueous disposal option as a method of controlling oxidation of sulfide minerals: Column studies, MEND Report ID: 2.12.1e

MEND 2000. Flooding of Pre-Oxidized Mine Tailings: Mattabi Case Study, MEND Report ID: 2.15.1a

MEND 1999. Assessing the Subaqueous Stability of Oxidized Waste Rock, MEND Report ID: 2.36.3

MEND 1998. Evaluation of man-made subaqueous disposal option as a method of controlling oxidation of sulphide minerals – Background and general description, MEND Report ID: 2.12.1b

MEND 1998. Design Guide for the Subaqueous Disposal of Reactive Tailings in Constructed Impoundments, MEND Report ID: 2.11.9

MEND 1997. Subaqueous Deposition of Tailings in the Strathcona Tailings Treatment System, MEND Report ID: PCA -1

MEND 1997. Evaluation of Techniques for Preventing Acidic Rock Drainage, MEND Report ID: 2.35.2b

MEND 1996. Review of Use of an Elevated Water Table as a Method to Control and Reduce Acidic Drainage from Tailings, MEND Report ID: 2.17.1

MEND 1996. Review of MEND Studies on the Subaqueous Disposal of Tailings (1993-1995), MEND Report ID: 2.11.1e

MEND 1996. Geochemical assessment of the Equity Silver tailings pond, MEND Report ID: 2.11.5c

MEND 1996. Geochemical assessment of subaqueous tailings disposal in Anderson Lake, Manitoba: 1993-1995 study program, MEND Report ID: 2.11.3abc

MEND 1996 Shallow Water Covers – Equity Silver Base Information Physical Variables, MEND Report ID: 2.11.5ab

MEND (1995): Review of In-Pit Disposal Practices for the Prevention of Acid Drainage - Case Studies, Mend Report 2.36.1

MEND 1995. Geochemical Assessment of Subaqueous Tailings Disposal in Buttle Lake, British Columbia 1993 Study Program, MEND Report ID: 2.11.4a

MEND 1994. Flooding of a Mine Tailings Site – Solbec Cupra. Suspension of Solids: Impact and Prevention, MEND Report ID: 2.13.2b

MEND 1993. Panel Wetlands – A Case History of Partially Submerged Pyritic Uranium Tailings Under Water, MEND Report ID: 3.12.2

MEND 1993. Literature Review Report: Possible Means of Evaluating the Biological Effects of Sub-Aqueous Disposal of Mine Tailings, MEND Report ID: 2.11.2a

MEND 1992. Chemical diagenesis of submerged mine tailings in Benson Lake and natural sediments in Keogh Lake, Vancouver Island, British Columbia, MEND Report ID: 2.11.1c-b

MEND 1992. A Preliminary Biological and Geological Assessment of Subaqueous Tailings Disposal in Benson Lake, British Columbia, MEND Report ID: 2.11.1c

MEND 1992. A critical review of MEND studies conducted to 1991 on subaqueous disposal of tailings, MEND Report ID: 2.11.1d

MEND 1990. Geochemical Assessment of Subaqueous Tailings Disposal in Buttle Lake, British Columbia, MEND Report ID: 2.11.1b-a

MEND 1990. Geochemical Assessment of Subaqueous Tailings Disposal in Anderson Lake, Snow Lake Area, Manitoba, MEND Report ID: 2.11.1b-b

MEND 1990. Geochemical assessment of subaqueous tailings disposal in Mandy Lake, Flin Flon area, Manitoba MEND Report ID: 2.11.1b-c

MEND 1990. A preliminary assessment of subaqueous tailings disposal in Anderson Lake, Manitoba, MEND Report ID: 2.11.1a-c

MEND 1990. A preliminary assessment of subaqueous tailings disposal in Mandy Lake, Manitoba, MEND Report ID: 2.11.1a-d

MEND 1990 A preliminary assessment of subaqueous tailings disposal in Benson Lake, British Columbia, MEND Report ID: 2.11.1a-b

MEND 1989. Subaqueous disposal of reactive mine wastes: An overview, MEND Report ID: 2.11.1a